Colonial Legacy and Land Market Formality

Harari, Mariaflavia and Wong, Maisy

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Mariaflavia Harari†
University of Pennsylvania

Maisy Wong‡
University of Pennsylvania and NBER

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Abstract

We study the role of Dutch colonial institutions on urban development for the megacity of Jakarta, Indonesia. Using historical maps of Dutch settlements and a rich granular database, we implement a boundary discontinuity design comparing locations within 200 meters of Dutch boundaries. We find that historical Dutch areas today have significantly lower parcel density, are more likely to have formally registered parcels, and have more regular parcel layout, pointing to the importance of planning and mapping. Dutch settlements are also more likely to appear formal, as per a photographic index that ranks the appearance of neighborhoods. More broadly, Dutch areas are 11 percentage points more likely to have tall buildings (with more than 3 floors) and have 17 log points higher assessed land values. We consider channels such as natural advantage, direct Dutch investments, and land market institutions.

JEL Classifications: R14, R31, R48
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†Corresponding author. Wharton Real Estate. 428 Vance Hall, 3733 Spruce Street, Philadelphia, PA 19104-6301. Email: harari@wharton.upenn.edu.

‡Wharton Real Estate. 434 Vance Hall, 3733 Spruce Street, Philadelphia, PA 19104-6301. Email: maisy@wharton.upenn.edu.

1 Introduction

Developing countries are urbanizing rapidly, amidst significant institutional challenges. Weak land market institutions are one of the key frictions (Henderson and Liu, 2023) and have been associated with lack of investment, slums, and sprawl. Economists have pointed to property rights as being paramount to promote investments in durable capital, which in turn have long-lasting implications for the spatial distribution of economic activity (Djankov et al., 2022).

This paper sheds light on the persistent effects of land market institutions on urban development by studying the role of Dutch settlements in Jakarta, Indonesia. Following the establishment of a Dutch East India Company trading post in the 17th century, as the Dutch settled in Batavia (present-day Jakarta), they established individual property rights and cadastral mapping according to the European legal tradition in Dutch settlements, while leaving the local customary land rights in place elsewhere, leading to a dual tenure system.

It is challenging to identify the causal impact of land market institutions because institutions typically vary across countries rather than within cities. We make progress by studying historical Dutch settlements within the city of Jakarta. We draw upon historical maps detailing boundaries of areas under Dutch land rights at independence, allowing us to implement a boundary discontinuity design comparing modern development outcomes on either side of the Dutch boundaries. The identifying assumption is that modern determinants of location quality change smoothly across Dutch boundaries within 200 meters, conditional on controls and granular fixed effects.

Our research design centers around high-resolution and comprehensive data from several sources. We measure multiple aspects of land market formality using cadastral maps of land parcels, legal status in the land registry, administrative data on land use patterns, and assessed land values. We also collected an innovative photographic sample to measure building heights and to develop a rank-based index of formality (Harari and Wong, 2024). We overlay Jakarta with a grid of 75-meter pixels and draw a representative sample of pixels from this grid. We then collect and hand-code photos from Google Streetview or taken by our own field team (in areas inaccessible to Google streetcars). Other auxiliary data capture historical and modern amenities. Our primary unit of analysis is the 75-meter pixel and the estimation sample includes 4,396 pixels.

The first finding is that historical land tenure patterns continue to shape urban development in modern Jakarta. Dutch settlements have lower parcel density (less fragmented land) compared to observably identical adjacent non-Dutch areas within 200 meters. The effect size is large, with 10.56 fewer parcels per pixel relative to the control group mean of 26 parcels. Intuitively, more fragmented land can complicate the land assembly process to the extent that developers require contiguous land parcels for building high-rises (Brooks and Lutz, 2016). Moreover, Dutch settlements are 4 percentage points more likely to have parcels that are registered in the cadastral system, relative to a mean of 81 percent for non-Dutch areas. Dutch settlements are also more likely to appear formal from our photo index (effect size of 0.25 relative to a control group mean of 2.67, where higher values correspond to greater formality).

A key threat to identification is that the Dutch chose to settle in more desirable locations so that the findings above could be confounded by unobserved location quality. We establish that Dutch and non-Dutch settlements are indeed significantly different for a set of pre-determined topographic attributes but these differences disappear once we include boundary fixed effects and restrict the sample to within 200 meters of Dutch boundaries. Plausibly, neighborhood quality could have differed discontinuously at the Dutch boundary during colonial times, while contemporaneous determinants of modern urban development are likely common within 200 meters. We also perform a bounding exercise finding that unobserved selection would have to be more than twice as important as observed factors to explain away our main estimates (Oster, 2019).

We further probe confounding due to unobserved quality by comparing early versus late Dutch settlements. The historical maps indicate that early Dutch settlements were more central, whilst later settlements were farther south from the city center. To the extent that the Dutch settled preferred locations first, if the impacts were driven by unobserved quality we should see greater formality in earlier settlements, but we do not.

Next, we explore other channels through which Dutch settlements can have persistent impacts on urban development. We begin by considering direct effects through physical Dutch investments. First, we examine durable factors such as surviving colonial landmarks and buildings. The vast majority of the original Dutch buildings had been demolished by the 1960s, suggesting that the persistence is not mechanically driven by differences in colonial structures across the boundary. In fact, we continue to find similar estimates after dropping pixels within 500 meters of the (few) surviving colonial structures, suggesting that our main effects are not driven by these durable investments.

Second, we consider infrastructure and amenities from colonial times that are documented in our historical maps but no longer present in modern Jakarta. These include sanitation and health infrastructure like wells and pipes, public amenities such as concert halls and academies, and private amenities such as hotels. These investments could have attracted higher-income residents and spurred more formalization and titling. However, proximity to these investments is similar on either side of Dutch boundaries, within our 200-meter boundary analysis.

In addition, economies of density can contribute to persistence by coordinating economic activity, leading to network effects and spillovers (Bleakley and Lin, 2012). We investigate this channel by estimating spatial decay patterns away from Dutch boundaries. For example, Dutch settlements could have attracted high-income residents, giving rise to positive spillovers and encouraging gentrification and formalization of nearby non-Dutch settlements. Alternatively, crowded informal settlements outside Dutch boundaries could have been associated with negative congestion externalities, leading to worse outcomes just inside Dutch settlements. Both sources of spatial spillovers will likely give rise to spatial decay patterns away from Dutch boundaries. We do not detect a significant enough decay pattern to change our conclusions.

Next, we turn to the persistent role of land market institutions. Interestingly, Dutch settlements have land parcels that are more regular in sizes and layout, which can facilitate land assembly and coordination (Libecap and Lueck, 2011). In particular, parcels in Dutch settlements are more aligned, with less variability in their angle orientations (the effect size is -5.47 degrees relative to a control mean of 32.13). Similarly, Dutch areas have less fragmented parcels as per the K land fragmentation index (effect size of 0.12, relative to a control mean of 0.45). These findings are consistent with Dutch land markets institutions facilitating the urban planning and land assembly process (Henderson and Liu, 2023).

We further explore heterogeneity by the historical land use of non-Dutch areas. Areas that were not under the Dutch legal system at independence were (i) empty (ii) cultivated with rice or orchards or (iii) "kampungs", i.e. traditional native settlements.[1] Outcomes for Dutch areas today are similar to those in former orchards, while we see less formality today in former rice areas and the least formality in kampung settlements. Interestingly, while all non-Dutch areas had customary land rights, land rights associated with orchards were individual while those associated with rice were collective. Overall, among the potential channels of persistence, we find relatively more support for the role of land market institutions, such as land registration and planning.

[1] *Kampung* is a colloquial term used in Indonesia to describe traditional (rural and urban) villages and, today, informal settlements.

Finally, we find that present-day urban development outcomes are also stronger in Dutch settlements. In particular, Dutch areas are 11 percentage points more likely to have tall buildings (more than 3 floors) and have 17 log points greater assessed land values. Here, we expand to a larger 500-meter boundary discontinuity analysis for more power, but the patterns are qualitatively similar for the 200-meter sample. Dutch areas also have better access to present-day amenities such as schools, hospitals, police, and bus stops and have higher density of office buildings.

We reinforce our findings with a series of robustness checks. We show that the main results of Dutch settlement impacts on formality continue to hold if we drop boundaries that coincide with waterways or railways. We also considered optimal bandwidths and alternative ways to construct boundary segment fixed effects. Finally, the results are robust to allowing spatial correlation in standard errors (Conley, 1999).

Put together, we make three contributions to the literature on land market institutions and urban development. First, we implement a boundary discontinuity analysis to provide causal evidence of the persistent impacts of Dutch institutions within the megacity of Jakarta. Second, we assemble rich measures of land market formality and urban form. Third, we leverage the setting of historical Dutch colonial settlements to shed light on potential channels.

We are closely related to the literature on land market institutions and urban form in developing countries. Baruah et al. (2021) show a persistent legacy of colonial planning institutions on urban structures across former French versus British colonies while Fredriksson et al. (2023) find that common law legal origin is associated with fewer slums. Aside from colonial institutions, there are also studies exploring other pathways to enhance property rights institutions through titling programs (Field, 2007; Galiani and Schargrodsky, 2010), sites and services (Michaels et al., 2021), or the role of local leaders (Manara and Regan, 2022). Another strand of the literature examines urban development in a context with dual, formal and informal land markets in Nairobi (Henderson et al., 2020), Kampala (Bird and Venables, 2019), and Chile (Gonzales and Undurraga, 2024).

We are also related to the literature on the persistent implications of colonial institutions for developing countries. There is an established literature documenting the negative impacts of extractive colonial institutions (Acemoglu et al., 2001, 2002; Dell, 2010; Lowes, 2016). Other work considers impacts on legal institutions (La Porta et al., 2008), state capacity (Ali et al., 2018), land taxation (Banerjee and Iyer, 2005), and long-run development outcomes through investments and manufacturing (Dell and Olken, 2019).

The rest of the paper proceeds as follows. Section 2 discusses the background, Section 3 describes the data, Section 4 describes the empirical strategy and presents our main results, Section 5 explores potential channels, Section 6 discusses impacts on overall urban development, Section 7 describes robustness tests, Section 8 concludes.

2 Background

Dual land markets, formal and informal, are a tangible manifestation of weak land market institutions that is common to many cities in developing countries, with important implications for urban growth (Henderson and Liu, 2023). This duality often has its roots in the colonial past of cities and the ensuing overlap of legal domains, where customary land rights coexist with those introduced by the colonizers. This section focuses on the history of Dutch settlements and land markets institutions in Jakarta.

2.1 History of Dutch Settlements

Dutch presence in Indonesia dates back to the 17th century, when the Dutch East India Company established a trading base in the port of Batavia (present-day Jakarta) to facilitate and control commodity trade in the region. The Dutch settlements in our study were largely built in the 19th through early 20th centuries, during a period of inland territorial expansion by the Dutch to promote agricultural production and the colonial plantation economy. Malaria and other disease outbreaks induced the Dutch to expand further away from the coast, and spurred investments in water management and sanitation. Settlements followed Dutch urban planning practices and the "garden city" principle, with grid-like roads, canals, and low density. Outside Dutch settlements were orchards, rice fields, and traditional "kampung" settlements, where different ethnic groups segregated into different enclaves. The early 20th century marked a program of "kampung verbetering" (kampung improvement), providing sanitation in the traditional non-Dutch settlements, with the goal of managing negative externalities from crowding.

In 1949 Indonesia gained independence from the Netherlands. The newly-formed government pursued a strategy of nation building and severing ties with the colonial past. Dutch nationals were expelled and urban planning efforts in the capital city of Jakarta focused on the creation of a National Monument and other landmarks related to Indonesia's history, to replace colonial ones. Until recent years, there were limited efforts to preserve

Dutch structures, leading to only few colonial buildings remaining in place today (Colombijn, 2022).

2.2 Land Markets and Urban Development in Jakarta

In Jakarta, the Dutch implemented a system of indirect rule, whereby the municipality governed the Dutch settlements only, while the surrounding areas were controlled indirectly subcontracting the government to local leaders. Under this dual system there were two different types of land: *bebouwede-kom* (literally "built-up" areas) under Dutch land rights and *niet bebouwde-kom* ("not built") under local Javanese land rights (*adat* law) (Kusno, 2015).

Dutch areas were characterized by Western land titling, featuring secure and tradeable ownership rights and institutionalized land registration and cadastral mapping. By 1874 the land registry system included a cadastral office featuring an engineer, value assessor, and land surveyor (Fakih, 2023). The customary rights system featured a variety of land rights, including communal use rights. Customary titles were recorded by village chiefs and not surveyed by an official surveyor (Leaf, 1993). These institutional differences resulted in native Indonesians having weaker claims to their land compared to Europeans.

The Dutch implemented extensive mapping, partly to enforce the segregation of different groups in ethnic enclaves (Cowherd, 2021). The historical maps we use (Figure A1) report the boundaries of *bebouwede-kom* areas in Jakarta at independence.

In 1960 the Basic Agrarian Law was passed, with the intent of establishing a unified land rights system that superseded Dutch and customary land rights. It also created the National Land Agency charged with facilitating the implementation of this new system by registering and administering land rights for all of Indonesia. However, the registration process to convert informal land rights to formal has been challenged by significant transaction costs and fees, difficulty verifying tenure status and resolving disputes, and courts that are backlogged. Today, Indonesia is still characterized by dual land markets (Leaf, 1993). Customary rights (*hak girik*) are unofficially secured by property tax records, sales receipts, and other documents. They are tradeable, with transactions recorded in local administrative offices (localities known as *kelurahan*).

This dual system of land markets has direct implications on the urban development process for Jakarta. Urban planners' approaches towards formal and informal settlements have evolved through Jakarta's Master Plans. The 1960 Master Plan prioritized upgrading kampungs through investments in sanitation and roads, as more Indonesians began to move into Jakarta after the Dutch left. As the city grew, the 1985-2005 Master Plan began to envision the redevelopment of kampungs and the creation of business districts beyond the city's historic center. However, this transition was interrupted by an oil crisis in 1986 and by the Asian Financial Crisis in 1997, with the economy only recovering by the mid-2000's. Today, modern Jakarta is facing increasing land scarcity amidst rapid population growth. The city has been expanding into the sprawling metropolitan area of Jabodetabek,[2] the world's second-largest. The most recent Jakarta Master Plan aims to address concerns of overpopulation, a severe shortage in housing, and traffic congestion.

3 Data

Our primary units of observation are 75-meter by 75-meter pixels, which we obtained by overlaying a grid of 95,000 pixels over the city of Jakarta.[3] For our empirical analysis we also consider localities (comparable in area to census tracts in the U.S.), the local administrative units responsible for collecting property taxes and registering property transfers of ownerships.

Maps of Dutch Settlements. We identify Dutch areas from a series of historical maps, primarily a 1959 U.S. Army map (U.S. Army Map Service, 1959) (with 25 meters resolution), which reflects the city's land use at independence, and one from 1937 (G. Kolff & Co, 1937) (11 meters). These maps clearly distinguish "bebouwde kom" areas that were settled by the Dutch under European land rights from areas that were under cultivation, empty, or "kampungs".

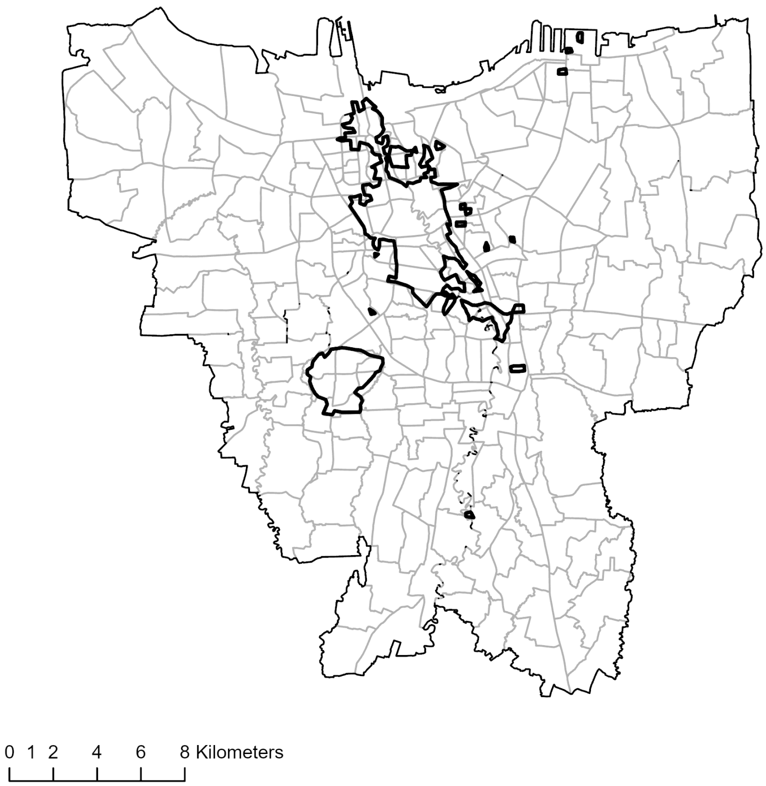
Figure 1 displays a map of the city of Jakarta with Dutch settlements (black polygons) as well as locality boundaries (gray). For each pixel, we calculate the distance to the closest Dutch boundary and the second closest. We then use these distances to determine the control group for the boundary discontinuity analysis (outside the Dutch settlements but within 200 meters for the closest Dutch boundary) and to avoid contamination (we drop observations that are within 200 meters of the second closest Dutch boundary). We assign a boundary fixed effect to each polygon in the map. Our results are robust to different

[2] Jabodetabek comprises Jakarta and the adjacent municipalities of Bogor, Depok, Tangerang, and Bekasi.

[3] This is the unit of analysis we used to construct our photographic sample (see Harari and Wong (2024) for more details of the sampling procedure).

approaches to define boundary fixed effects and are robust to excluding the smallest Dutch polygons.

Figure 1: Map of Historical Dutch Settlements in Jakarta



Notes: Map showing Dutch boundaries (thick black border) and locality boundaries (gray).

Measuring Formality. There is no standardized metric to quantify formality in land markets. We develop three proxies that capture several dimensions in which formal and informal areas differ. First, we consider parcel density (number of parcels in each pixel) based on digital cadastral maps created by the Jakarta Department of Housing in 2011. Second, we calculate the area share of each pixel corresponding to unregistered parcels, from a unique digital land map created and made public in 2020 by the Indonesian National Land Agency.

Third, as described in Harari and Wong (2024), we hand-coded a rank-based index of formality from an innovative photographic sample. The index ranges from 0 (very informal) to 4 (very formal). Examples can be found in Figure A2 in the Appendix. Research assistants were instructed to rank photos based on characteristics of the neighborhood (including the density and irregularity of structures, and cleanliness) and of the buildings (such as the durability of materials and the size of windows). Our sample of photos is representative of the entire city of Jakarta and is drawn from a combination of Google Streetview and photos taken by our team in the field.

Heights and Land Values. Our primary height outcome is from our photo sample. We define an indicator equal to one if the tallest building in the pixel is above three floors. Pixels with no buildings (4% of the sample), corresponding to large roads, parks, or empty lots, were assigned a height of 0 and a "no building" dummy. For assessed values, we obtained a digital map in 2015 through the Smart City Jakarta initiative. We have assessed land values in Rupiah per square meter for nearly 20,000 sub-blocks (the smallest zoning unit in Jakarta). Harari and Wong (2024) describe validation exercises to compare assessed values with market data.

Current Amenities. We observe modern public amenities in 2016 from OpenStreetMap, measuring distances of each pixel to the closest school, hospital, police station, and bus stop. In addition, we also compute the land share of each pixel corresponding to retail and office buildings respectively, based on a 2014 administrative land use map from the Jakarta Government website.

Historical Amenities. We capture the distance, in logs, from a number of historical landmarks during Dutch colonial times. We code the location of notable buildings from the 19th and 20th century corresponding to the parts of the city that appear to have the most economic activity based on the businesses, public buildings, and amenities listed in three historical maps we digitized (Visser Co te Batavia, 1887; Officieele Vereeniging voor Toeristenverkeer, Batavia, 1930; U.S. Army Map Service, 1959). We consider the 1821 Concert Hall (later used as the Japanese headquarters during the occupation), the 1829 Hotel des Indes (at the core of the expat community where most embassies were), the 1932 Bioscoop Metropool (Jakarta's first mall), and the Akademi Nasional (which would host in 1949 the oldest private university in Jakarta) located in suburban areas in South Jakarta.

Surviving Dutch Structures. We hand-collected the location of Dutch buildings that are still in place in today's Jakarta. We consulted a number of on-line sources including travel blogs, tourism websites, and a Wikipedia page on colonial architecture in Jakarta and verified the presence of each building from Google Street View. The resulting database includes 72 buildings, concentrated in the northern part of the central Dutch areas. These include

Dutch administrative buildings which have continued on as museums or government buildings, but also a number of private residences and warehouses that tend to be in dilapidated condition.

Topography controls. We consider a number of pre-determined controls to capture natural advantage. We include slope and elevation from the ASTER Global Digital Elevation Model (NASA and METI, 2011). We capture the hydrological determinants of local flood proneness through three proxies (Jati et al., 2019): log distances from the coast and from the nearest permanent or semi-permanent water body, from the ECJRC Global Surface Water Dataset (Pekel et al., 2016), and flow accumulation, a measure of exposure to flooding based on relative slopes.[4] Finally, we include bedrock depth, which affects the engineering costs of building high-rises (Ahlfeldt et al., 2023), from the SoilGrids 250-meter dataset (Hengl et al., 2017).

4 Empirical Strategy

4.1 Boundary Analysis

As our main estimating equation we consider a boundary discontinuity design (BDD) where we restrict the sample to pixels within 200 meters on either side of Dutch boundaries:

$$Y_{ijb} = \beta_1 \text{Dutch}_{ijb} + \beta_2 \text{Dist}_{ijb} + \beta_3 \text{Dist}_{ijb} \times \text{Dutch}_{ijb} + \beta_4 \mathbf{X}_{ijb} + \gamma_j + \delta_b + \varepsilon_{ijb} \quad (1)$$

where unit i is a 75-meter pixel in locality j and assigned to boundary b. We allow for separate linear distance controls ($Dist_{ijb}$) to the nearest Dutch boundary on either side (Michaels et al., 2021). For the treatment group, we assign a value of one for $Dutch_{ijb}$ for pixels inside a Dutch settlement, within 200 meters from the boundary. For the control group, we include pixels that are not in Dutch settlements, within 200 meters of the closest Dutch boundary (to be comparable to Dutch settlements) and more than 200 meters away from the second closest Dutch boundary (to avoid contamination). Furthermore, we exclude pixels that intersect the area of the current Merdeka Square (formerly *Koningsplein*), since this area has always been set aside for purely public use as a ceremonial square and parading

[4]We verify that our hydrology controls are strong predictors of flood damage in Jakarta, as measured by whether a hamlet is classified as “flood-prone” in OpenStreetMap.

ground. While it is in the middle of the Dutch zone our historical maps do not consider it as "bebouwde kom". Our primary specification includes 108 fixed effects for localities (γ_j) and 26 fixed effects for the closest boundary for pixel i (δ_b). ε_{ijb} is assumed to be an idiosyncratic error term. Standard errors are clustered by localities but we also demonstrate robustness by allowing for spatial autocorrelation (Conley, 1999).

The key parameter of interest is β_1 which we interpret as the causal impact of being in a Dutch settlement on formality today. Our identifying assumption is that conditional on controls, unobserved neighborhood quality changes smoothly across Dutch boundaries when we compare pixels within 200 meters.

A key threat to identification is persistence of historical quality differences because the Dutch likely chose to settle in neighborhoods that were higher-quality in the past. In order to illustrate the role of historical Dutch factors versus potential confounders, let ξ represent location quality for pixel i in locality j and assigned to boundary b. Assume location quality evolves over time according to the following process (Lee and Lin, 2018): $\xi_{ijbt} = \rho\xi_{ijb,t-1} + u_{jbt} + \varepsilon_{ijbt}$ where $\rho < 1$, u_{jbt} is a contemporaneous neighborhood component, and ε_{ijbt} is a mean 0 idiosyncratic shock. Furthermore, to trace back to historical differences, let the period right before the Dutch settled be $t = 0$ and modern Jakarta be T years later. We can then decompose the difference comparing Dutch (D) and non-Dutch (ND) settlements $E(\xi_{ijbt}|D_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b)$ - $E(\xi_{ijbt}|ND_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b)$, into two components stemming from historical factors and contemporaneous factors.

$$\begin{aligned} &\underbrace{\rho^T \left[E\left(\xi_{ijb0}|D_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b\right) - E\left(\xi_{ijb0}|ND_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b\right)\right]}_{\text{Historical factors}} \\ &- \underbrace{\left[E(u_{jbt}|D_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b) - E(u_{jbt}|ND_{ijb}, \mathbf{X}_{ijb}, \gamma_j, \delta_b)\right]}_{\text{Common contemporaneous shocks}} \end{aligned} \tag{2}$$

It is possible that the Dutch chose to settle in better locations and that ξ_{ijb0} could have been discontinuously different across Dutch boundaries during colonial times. Our identifying assumption is that pre-Dutch differences in quality are less important now (ρ<1) and unobserved contemporaneous factors are common across Dutch and non-Dutch locations, once we restrict to pixels within 200 meters of Dutch boundaries and condition on controls, boundary, and locality fixed effects (δ_b and γ_j). The next sub-sections unpack potential ways in which historical Dutch settlements could lead to persistent differences today. Some factors are likely obsolete by now while other factors may persist.

Table 1 compares pre-determined characteristics across Dutch and non-Dutch pixels.

Column 1 includes the full sample of 95,000 pixels with no fixed effects, showing that Dutch pixels are associated with lower elevation (3.69 meters), steeper slope (0.5 degrees), and are closer to the coast (32 log points). Column 2 shows that these differences disappear when we implement our BDD analysis using the primary estimation sample of 4,396 pixels that are within 200 meters of the Dutch boundaries. Here, we include boundary fixed effects and locality fixed effects. Standard errors are clustered by locality.

Table 1: Comparing Dutch and non-Dutch Locations

Sample:	OLS	BDD
	Full	200m
	(1)	(2)
Elevation, m	-3.69**	0.88
	[0.02]	[0.12]
Slope, Degrees	0.50***	0.43
	[0.01]	[0.12]
Flow Accumulation	0.05	0.33
	[0.63]	[0.50]
Log Distance to Coast	-0.32***	0.0009
	[0.01]	[0.91]
Bedrock Depth, m	-0.29	-0.88
	[0.76]	[0.11]
Log Distance to Surface Water	-0.05	0.04
	[0.73]	[0.19]
N	95235	4396

* 0.10 ** 0.05 *** 0.01

Notes: This table reports regressions with our controls as the dependent variables and the Dutch settlement indicator as the key regressor. For each variable, the top row reports the coefficient, and the bottom row reports the p-value in brackets. The unit of analysis is a pixel. Column 1 includes the full sample of 95,235 pixels with no fixed effect. Column 2 restricts the sample to 4,396 pixels within 200 meters of the closest Dutch boundary. Standard errors are clustered by locality.

4.2 Impacts on Formality

Table 2 reports our main estimates of the impact of historical Dutch settlements on formality today. Column 1 restricts the sample to 4,396 pixels within 200 meters of Dutch boundaries. We include boundary fixed effects, linear distance controls to Dutch boundaries (separately on each side), locality fixed effects, and topography controls. Standard errors are clustered by locality.

Column 1 indicates that Dutch settlements have lower parcel density (-10.56 parcels per pixel) compared to otherwise comparable pixels just outside the Dutch boundary. Intuitively, greater parcel density tends to be associated with more fragmented land ownership.

This add complexity to the land assembly process, to the extent that a developer requiring contiguous land will need to negotiate with more owners, potentially exacerbating holdout problems. This is a large effect relative to the control group mean of 26. Here, we also include the log lengths of all the roads in a pixel as an additional control to address the concern that the presence of roads will mechanically lead to more fragmented land parcels.

Table 2: Effect of Dutch on Formality

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
Sample:	BDD 200m	BDD 200m	BDD 200m
	(1)	(2)	(3)
Dutch	-10.56***	0.04**	0.25**
	(2.05)	(0.02)	(0.12)
N	4396	4396	1378
R-Squared	0.38	0.29	0.29
Control Group Mean	26.00	0.81	2.67
Topography	Y	Y	Y
Locality FE	Y	Y	Y
Boundary FE	Y	Y	Y

* 0.10 ** 0.05 *** 0.01

Notes: The unit of analysis is a pixel. The key regressor is an indicator that is 1 for a pixel in Dutch settlements. All columns include pixels within 200 meters of a Dutch settlement boundary while excluding those within 200 meters of a second Dutch boundary. All columns control for distances to the Dutch boundary by treatment status and Dutch boundary fixed effects. Column 1 reports the effect of Dutch on parcel density, with the log lengths of all the roads in a pixel as an additional control. It includes 108 locality fixed effects, 58 of which have within-group variation, and 26 boundary fixed effects. Column 2 reports the effect of Dutch on share of a pixel that has registered parcels. Column 3 reports the effect of Dutch on the photo index (greater values are more likely formal) with controls for strata fixed effects from our photographic survey and an indicator for pixels with no photo index. Standard errors in all columns are clustered by locality.

Column 2 shows Dutch settlements have a 4 percentage point higher share of registered land (relative to a mean of 81 percent). This captures the legal registration status of land parcels. Finally, column 3 utilizes a sample of 1,378 pixels included in our photos sample, for which we have coded our rank-based formality index. Higher values of the photo index correspond to more formal areas. We find an effect of 0.25, relative to a control mean of 2.67. Here, we also include strata fixed effects from our photographic survey and an indicator for pixels with no index (empty land, interior photos, or roads where we cannot code the index). We discuss spatial spillovers and other robustness below.

5 Potential Channels

Why might the presence of Dutch settlements many decades ago still matter for land markets today? We explore several potential channels that are salient in the literature on persistence (Hanlon and Heblich, 2020).

5.1 Natural Advantage

Fixed natural features (e.g. mountains or rivers) can have persistent value in attracting households and firms (Lee and Lin, 2018). We control for observable natural amenities through our controls and fixed effects. However, there could be unobserved sources of natural advantage.

Unobserved Selection. One threat to identification is that unobserved determinants of formality may also change discontinuously at the boundary. To quantify how large this potential bias can be, we follow Oster (2019) to produce two metrics. First, we infer how important unobserved factors have to be (relative to observed factors) to explain away our main estimates in Table 2. Second, we calculate a bias-corrected estimate of β_1, assuming observed and unobserved factors are equally important. Table 3 reports the specifications from the table above (even columns) and also a parsimonious specification without locality fixed effects and without controls (odd columns). We report these two metrics at the bottom of the table.

For parcel density, the parsimonious specification delivers an estimate of -12.91 and an R-squared of 0.17, relative to -10.56 for our preferred estimate (R-squared of 0.38). We calculate a ratio of 8.28, implying that unobserved factors have to be eight times more important than observed factors to explain away the estimated effect. We use the formula $\frac{\beta_C}{(\beta_U - \beta_C)} * \frac{R_C - R_U}{R_{Max} - R_C}$, where U denotes uncontrolled and C denotes controlled.[5] Intuitively, this ratio will be large if the Dutch effect is stable (first term), the R-squared improves a lot with controls (numerator of second term), or there is less remaining variation to explain (denominator of the ratio in the second term). We also report a bias-corrected estimate of β_1, where -9.28 assumes both observed and unobserved factors have equal importance. Our conclusions are similar for the other outcomes. For share registered, the ratio is 2.18

[5] We calculate 8.28 from $\frac{-10.56}{(-12.91+10.56)} * \frac{0.38-0.17}{0.49-0.38}$. We assume $R_{Max} = 1.3$ and $R_C = 0.49$ (Oster, 2019). It is unlikely that our outcomes will have a maximum R-squared of 1, given measurement error (Alesina et al., 2016).

(above the heuristic threshold of 1 (Oster, 2019)) and the bias-corrected estimate is 0.02. For the photo index, the ratio is 4.31 and the bias-corrected estimate is 0.19.

Table 3: Effect of Dutch on Formality, Robustness to Controls

Dependent variable:	**Parcel Density**		**Share Registered**		**Photo Index**	
Sample:	BDD 200m (1)	BDD 200m (2)	BDD 200m (3)	BDD 200m (4)	BDD 200m (5)	BDD 200m (6)
Dutch	-12.91***	-10.56***	0.08***	0.04**	0.37***	0.25**
	(1.74)	(2.05)	(0.01)	(0.02)	(0.08)	(0.12)
N	4396	4396	4396	4396	1378	1378
R-Squared	0.17	0.38	0.10	0.29	0.11	0.29
Control Group Mean	26.00	26.00	0.81	0.81	2.67	2.67
Delta		8.28		2.18		4.31
β_{adjusted}		-9.28		0.02		0.19
Topography	N	Y	N	Y	N	Y
Locality FE	N	Y	N	Y	N	Y
Boundary FE	Y	Y	Y	Y	Y	Y

* 0.10 ** 0.05 *** 0.01

Notes: The even columns repeat the specifications in Table 2. The odd columns are the same specifications but dropping controls and locality fixed effects. Standard errors are clustered by locality.

Early versus Late Dutch Settlements. We further assess selection by the Dutch, comparing early versus late Dutch settlements. The Dutch first settled near the port in the North of Jakarta, then expanded to inner areas. In Figure 1, early Dutch settlements correspond to those in the north and center of Jakarta, while the later settlements are in the south-west.

Interestingly, when we examine differences in the means of our outcomes, we do not find a pattern that suggests our effects are driven by unobserved quality due to Dutch sorting patterns. If this were the case, we would find greater formality in early versus late settlements, but we do not. In fact, parcel density is comparable (14.8 in early settlements, relative to 13.2 in later ones). The share of land that is registered and the photo index are, if anything, better in late settlements (0.88 and 0.94 registration share in early and late, respectively; 3.04 and 3.17 for the formality index in early and late, respectively).

5.2 Durable Capital

Past investments in buildings and infrastructure can also have lasting impacts because of the durability of the capital stock. In Jakarta, this is unlikely to be at play because the vast majority of the original colonial buildings were demolished or abandoned, in line with the nation building strategy pursued at independence. We further probe this channel by collecting information on the location of the 72 Dutch structures still in place in the city.

Table 4 repeats Table 2 but drops pixels within 500 meters of these surviving Dutch structures. If our main effects were driven by the enduring presence of colonial buildings, our estimated effect could be drastically muted after dropping nearby pixels. Instead, we find similar impacts for parcel density (-9.29 relative to -10.56), registered share (0.03 relative to 0.04), and the photo index (0.36 relative to 0.25), albeit with a slight loss of power.

Table 4: Robustness to Excluding Surviving Dutch Buildings

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
Sample:	BDD 200m (1)	BDD 200m (2)	BDD 200m (3)
Dutch	-9.29***	0.03	0.36***
	(2.11)	(0.02)	(0.13)
N	3326	3326	1068
R-Squared	0.40	0.27	0.31
Control Group Mean	25.49	0.83	2.72
Topography	Y	Y	Y
Locality FE	Y	Y	Y
Boundary FE	Y	Y	Y

* 0.10 ** 0.05 *** 0.01

Notes: This table is similar to Table 2 but drops pixels that are within 500m of a surviving Dutch colonial building.

5.3 Economies of Density

Economies of density can make it valuable to keep agglomerating in one place (e.g. even long after historical factors stopped being relevant (Bleakley and Lin, 2012)). Indeed, the Dutch introduced physical improvements to neighborhoods, such as drainage and water management, that may have attracted high-income households and lead to positive neighborhood spillovers. The concentration of Dutch residents could also be associated with more foreign businesses and economic activity that led to persistent agglomeration even after the Dutch left.

Agglomeration from Dutch Investments. Table 5 investigates whether historical amenities and public goods are statistically significantly different for Dutch versus non-Dutch pixels. Columns 1 to 4 examine distances to the 1821 Concert Hall, the 1829 Hotel des Indes, the 1932 Bioscoop Metropool (the Mall), and the Akademi Nasional. These are all colonial landmarks that mark the areas with the most amenities and economic activity during colonial times. Except for a 2 log point proximity difference for column 3 (small relative to a mean of 8.40), there are no significant differences. In column 5, we quantify that Dutch pixels are 2 percentage points more likely to have wells and pipes (mean of 0.54), consistent with Dutch investing to improve sanitation, but this effect is also small.

Table 5: Proximity to Dutch Investments

Dependent: variable	Log distance to Concert Hall	Hotel	Mall	University	Presence of Wells or Pipes
Sample:	BDD 200m (1)	BDD 200m (2)	BDD 200m (3)	BDD 200m (4)	BDD 200m (5)
Dutch	-0.02	-0.01	-0.02*	0.003	0.02**
	(0.01)	(0.01)	(0.01)	(0.003)	(0.01)
N	4396	4396	4396	4396	4396
R-Squared	0.98	0.97	0.95	0.99	0.96
Control Group Mean	8.39	8.46	8.40	9.16	0.54
Topography	Y	Y	Y	Y	Y
Locality FE	Y	Y	Y	Y	Y
Boundary FE	Y	Y	Y	Y	Y

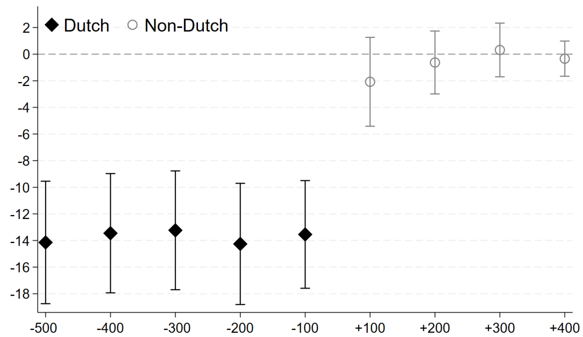
* 0.10 ** 0.05 *** 0.01

Notes: The dependent variables are log of distance to the 1821 Concert Hall, 1829 Hotel des Indes, 1932 Bioscoop Metropol (Jakarta's first mall), and the university, Akademi Nasional (columns 1 through 4), and an indicator for the presence of wells or pipes within 1000 meters of a pixel (column 5). The sample includes 4,396 pixels. Standard errors are clustered by locality.

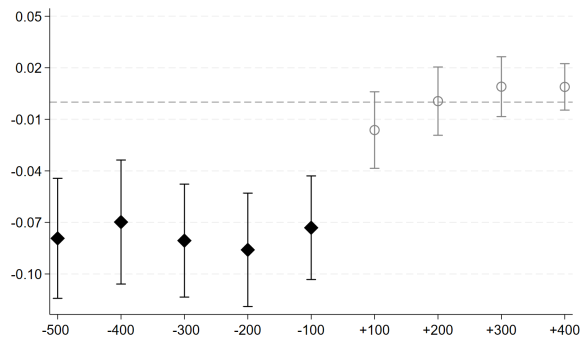
Spatial Decay from Dutch Boundaries. As an additional test for economies of density, we consider spatial decay patterns. It is possible that Dutch locations attracted higher-income households, leading to more gentrification and formalization. If this were the case, we would likely see spillovers from Dutch to non-Dutch pixels nearby, with more formality just outside Dutch boundaries. Along the same lines, non-Dutch pixels could be more likely to attract informal settlers, leading to crowding and negative congestion externalities, which could reduce formality in adjacent Dutch areas. Both sources of spatial spillovers would lead to a spatial decay pattern moving away from Dutch boundaries.

Figure 2 shows spatial decay plots that extend our BDD analysis to 500 meters and estimate effects for each 100-meter bin. The omitted group is the outermost bin outside the Dutch settlement. Interestingly, there is a slight trend around the 100-meter bins, suggestive of positive spillovers from Dutch areas, but not large enough to be conclusive.

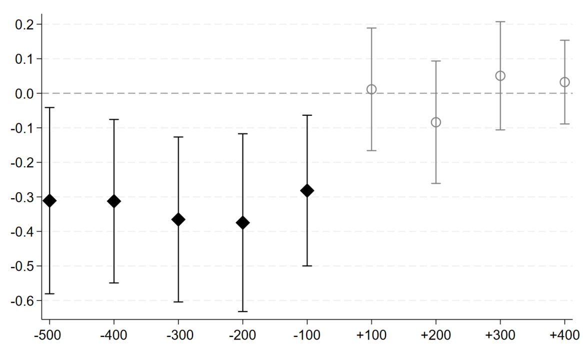
Figure 2: Spatial Decay: Distance from Dutch Boundaries



(a) Parcel Density



(b) Share Registered



(c) Photo Index

Notes: We employ a similar specification as our BDD analysis in Table 2, replacing distance to the Dutch boundary with dummies for different 100m-wide distance bins. The omitted group is the outermost distance bin outside Dutch settlements.

5.4 Land Market Institutions

Finally, outcomes may be different within Dutch boundaries because of land market institutions, which comprise a bundle of individual property rights, a formal registration system, cadastral mapping, and urban planning. The finding discussed above that parcels in Dutch areas are more likely to be recorded in the land registry suggests an important role for the land registration system. Table 6 below further explores whether areas within Dutch boundaries exhibit features associated with formal, planned neighborhoods. We consider two metrics of regularity, one based on the area sizes of parcels and one based on their orientation.

The K land fragmentation index (Januszewski, 1968) combines information on parcel count per pixel and average parcel area as follows:

$$K = \frac{\sqrt{\sum_{i=1}^{n} a_i}}{\sum_{i=1}^{n} \sqrt{a_i}}$$

where n is the number of parcels and a is the parcel size. This index ranges from 0, in the limit case of an infinite number of parcels, to 1, for the case of a single parcel; lower values indicate a higher degree of fragmentation. Fragmentation as captured by the K index increases when the range of parcel sizes is small and decreases as the area of large parcels increases and that of small parcels decreases.

Second, we consider the extent to which land parcels have similar orientation (Michaels et al., 2021). We calculate the standard deviation, in degrees, among the main angles of all parcels within a pixel. Higher values of this metric imply more variability in parcel orientation.

Column 1 of Table 6 reports that Dutch pixels have a higher K-index by 0.12 (relative to a control mean of 0.45). Column 2 shows Dutch settlements are more likely to have regularly oriented parcels, with a standard deviation lower by 5.47 degrees (relative to a control mean of 32.13). We lose observations for this outcome since we drop pixels with no parcels. These results echo those in Yamasaki et al. (2021) on the persistence in lot sizes in Japan.

Historical Land Use. In Table 7, we compare Dutch settlements to different types of non-Dutch locations. From our historical maps, we observe whether non-Dutch locations were *kampung* settlements where the locals resided, orchards, rice fields, or empty land (the

Table 6: Effect of Dutch on Parcel and Building Regularity

Dependent variable:	**K Index**	**Angle Variation**
Sample:	BDD 200	BDD 200m
	(1)	(2)
Dutch	0.12***	-5.47***
	(0.03)	(1.28)
N	4396	3458
R-Squared	0.32	0.28
Control Group Mean	0.45	32.13
Topography	Y	Y
Locality FE	Y	Y
Boundary FE	Y	Y

* 0.10 ** 0.05 *** 0.01

Notes: This table repeats Table 2 to focus on building regularity. Column 1 reports the effect on the K index, a measure of spatial consistency among buildings. Column 2 reports the effect on the angle variation, defined as the standard deviation of building angles within a pixel. We do not include pixels that have no buildings. Standard errors in all columns are clustered by locality.

omitted group). To explore heterogeneity, we expand to the 500-meter boundary sample with 9,736 pixels within 500 meters of the Dutch boundaries (but more than 200 meters from the second closest boundary to avoid contamination).

Column 1 shows that Dutch pixels continue to have the lowest parcel density (-6.28) followed closely by orchards (-5.34). The Dutch coefficient is not statistically different from the coefficient for orchards. Next, we find a weak positive effect for rice farms (1.13) followed by the highest parcel density for kampungs (8.75). This pattern echoes historical accounts associating orchards with individual land rights and traditional rice farms with communal land use rights (Boys, 1892), and with kampungs being the least formal.

Next, column 2 shows the largest effect for registration status in Dutch settlements (5 percentage points) followed by orchards (4), with both being statistically indistinguishable. The estimates are small for rice and kampung. The estimates for the photo index (column 3) are noisier.

Taken together, our investigation of channels points to an important role of land market institutions, such as land registration and planning.

Table 7: Hetereogeneity by Historical Land Use

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
Sample:	BDD 500m	BDD 500m	BDD 500m
	(1)	(2)	(3)
Dutch	-6.28***	0.05***	0.27**
	(2.07)	(0.02)	(0.13)
Orchard	-5.34	0.04	-0.27
	(8.11)	(0.08)	(0.40)
Rice	1.13	0.00	0.09
	(1.52)	(0.02)	(0.12)
Kampung	8.75***	-0.02	-0.06
	(1.69)	(0.01)	(0.09)
N	9736	9736	3163
R-Squared	0.41	0.28	0.81
Control Group Mean	24.96	0.81	2.74
Topography	Y	Y	Y
Hamlet FE	Y	Y	Y
Boundary FE	N	N	N

* 0.10 ** 0.05 *** 0.01

Notes: This table extends the BDD analysis in Table 2 to 500 meters and splits the non-Dutch areas to define mutually exclusive indicators for primary crop planted within each pixel (orchard or rice) versus historical kampung settlements. The omitted group is empty areas. Standard errors are clustered by locality.

6 Impacts on Urban Development

This section investigates whether Dutch settlements are associated with better urban development outcomes today. We examine building heights and assessed land values first, followed by access to amenities.

Heights and Land Values. Columns 1 and 2 of Table 8 report Dutch impacts for building heights using an indicator for buildings with more than three floors, per our photo sample. Dutch areas are 11 percentage point more likely to have tall buildings relative to a control mean of 22 percent. Here, we expand the sample to 500 meters for statistical power issues. The estimate for the 200-meter sample is positive (4 percentage points) but insignificant. We also examined log of number of floors but did not detect an effect. Columns 3 and 4 show that Dutch areas have higher assessed land values today with 8 and 17 log points for the 200m and 500m samples, respectively.

Table 8: Effect of Dutch on Heights and Land Values

Dependent variable:	1(Height>3)		Land values	
Sample:	BDD 200m (1)	BDD 500m (2)	BDD 200m (3)	BDD 500m (4)
Dutch	0.04	0.11**	0.08	0.17**
	(0.06)	(0.05)	(0.10)	(0.08)
N	1377	3162	659	1754
R-Squared	0.33	0.30	0.78	0.76
Control Group Mean	0.20	0.22	16.45	16.47
Topography	Y	Y	Y	Y
Locality FE	Y	Y	Y	Y
Boundary FE	Y	Y	Y	Y

* 0.10 ** 0.05 *** 0.01

Notes: Columns 1 and 2 report pixel-level regressions for the 200- and 500-meter boundary sample with an indicator for tall buildings (more than three floors). We also include strata fixed effects for our photographic sample and an indicator for pixels with no buildings. Columns 3 and 4 examine the impacts on assessed land values using are sub-block level regressions within 200 and 500 meters of Dutch boundaries. We include locality fixed effects and controls. Standard errors are clustered by locality.

Modern Amenities. Table 9 demonstrates that Dutch settlements have better access to modern amenities, as measured by distances to the closest school (-17 log points), hospital (-9 log points), police station (-8 log points), and bus stop (-24 log points). The last two columns examine land use patterns, finding no difference in retail density and 6 percentage points higher office density.

Overall, these patterns are consistent with Dutch settlements having better urban development outcomes.

7 Robustness

We discuss additional robustness checks in this section.

Optimal bandwidth. Table A1 repeats the analyses in Table 2 using the optimal bandwidth for each of the three outcomes, à la Calonico et al. (2014). The optimal distances are 276 meters for parcel density (column 1), 274 meters for share unregistered, and 320 meters for our photo index. The effect sizes are similar to the baseline ones when we repeat the boundary discontinuity regression using these new bandwidths: -11.36 for parcel density, 7 percentage points for the share registered, and 0.30 for the photo index.

Table 9: Access to Modern Amenities

Dependent variable:	Log distance to School	Hospital	Police	Bus stop	Retail Density	Office Density
Sample:	BDD 200m (1)	BDD 200m (2)	BDD 200m (3)	BDD 200m (4)	BDD 200m (5)	BDD 200m (6)
Dutch	-0.17*	-0.09*	-0.08*	-0.24***	-0.002	0.06***
	(0.10)	(0.05)	(0.05)	(0.07)	(0.01)	(0.02)
N	4396	4396	4396	4396	4396	4396
R-Squared	0.28	0.57	0.57	0.47	0.22	0.31
Control Group Mean	-1.40	-0.35	-0.25	-0.80	0.05	0.06
Topography	Y	Y	Y	Y	Y	Y
Locality FE	Y	Y	Y	Y	Y	Y
Boundary FE	Y	Y	Y	Y	Y	Y

* 0.10 ** 0.05 *** 0.01

Notes: The dependent variables are log of distance to the nearest school, hospital, police station, and bus stop (columns 1 through 4), and share of retail (column 5) and office development within a pixel (column 6). The sample includes 4,396 pixels. Standard errors are clustered by locality.

Coinciding boundaries. Table A2 drops 10 boundaries that coincide with historical waterways and railways. The corresponding regression estimates for Table 2 are similar to our baseline ones: -11.35 for parcel density (relative to -10.56 in the main estimates), 5 percentage points for share registered (relative to 4 percentage points), and 0.27 for the photo index (relative to 0.25).

Construction of Dutch boundary segments. Table A3 implements an alternative approach to assign Dutch boundary fixed effects. Figure 1 shows that the sizes of Dutch polygons are uneven. As an alternative to including Dutch polygon fixed effects, we superimpose a fishnet of 1 squared km grid cells spanning Jakarta and use it to arbitrarily split the Dutch polygons into boundary segments. We then assign a unique boundary identifier to each line segment which we use for boundary segment fixed effects. We then recalculate the distance from each 75-meter pixel to the nearest and second nearest boundary segment and implement a BDD design comparing pixels within 200 meters of Dutch boundaries, dropping contaminated observations that are close to other segments. The sample size is slightly smaller as there are more boundary segments and more potential for contamination. There are 97 boundary segment fixed effects instead of 27. Reassuringly, our estimates are similar to those in Table 2.

Conley standard errors. Table A4 replicates the analyses for the main outcomes in Table 2, allowing for spatial autocorrelation in standard errors over a range of distances, including

500 meters, 700 meters, and 900 meters (the implied radius of a locality). The p-values for the Dutch coefficient are at most 2 percent across all specification checks.

8 Conclusions

Land market institutions are central to the planning and functioning of cities. It is challenging to study the impact of institutions because they tend to vary across countries or cities. This paper makes progress using a boundary discontinuity design and a rich database of high-resolution outcomes within the city of Jakarta. We establish persistent impacts on formality and urban form in modern Jakarta when comparing Dutch versus non-Dutch settlements within 200 meters of Dutch boundaries. Notably, Dutch locations have lower parcel density, are more likely to have registered parcels, and are more likely to be ranked formal per our photo index. These areas are also more likely to have tall buildings and have higher assessed land values. We consider several potential channels that contributed towards persistence. We highlight an important role for institutions, including registration and regularity in the layout of parcels in Dutch settlements. We also show that the effects are unlikely to be explained away by differences in unobserved quality, spatial spillovers, or durable investments by the Dutch.

This paper focuses on the impact of historical Dutch settlements on land market formality and urban form in Jakarta. Directions for future research include shedding light on the bundle of property rights institutions and how different components influence urban development. It will also be important to explore broader avenues to enhance land market institutions and urban development, including titling programs, sites and services, and the role of urban planning and zoning regulations. As many cities in developing countries are characterized by a dual system of property rights, it would be interesting to study the evolution of these systems and how they shape the spatial distribution of economic activity in cities.

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Appendix Tables

Table A1: Robustness to Optimal Bandwidths

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
Sample:	BDD 200m	BDD 200m	BDD 200m
	(1)	(2)	(3)
Dutch	-11.36***	0.07***	0.30***
	(2.12)	(0.02)	(0.11)
N	12147	10000	2143
R-Squared	0.39	0.28	0.27
Control Group Mean	24.28	0.81	2.66
Topography	Y	Y	Y
Locality FE	Y	Y	Y
Boundary FE	Y	Y	Y

* 0.10 ** 0.05 *** 0.01

Notes: This table is similar to Table 2 but uses the optimal bandwidths instead of 200 meters as the cutoffs. The optimal bandwidths for parcel density, share registered, and photo index are 276, 274, and 320 meters, respectively.

Table A2: Drop Boundaries Near Railways and Waterways

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
Sample:	BDD 200m	BDD 200m	BDD 200m
	(1)	(2)	(3)
Dutch	-11.37***	0.05**	0.27*
	(2.39)	(0.02)	(0.14)
N	3446	3446	1065
R-Squared	0.38	0.29	0.30
Control Group Mean	25.59	0.81	2.68
Topography	Y	Y	Y
Locality FE	Y	Y	Y
Boundary FE	Y	Y	Y

* 0.10 ** 0.05 *** 0.01

Notes: This table is similar to Table 2 but drops 10 boundaries overlapping with either railways or waterways.

Table A3: Alternative Construction of Dutch Boundary Segments

Dependent variable:	**Parcel Density**	**Share Registered**	**Photo Index**
Sample:	BDD 200m (1)	BDD 200m (2)	BDD 200m (3)
Dutch	-9.85***	0.05**	0.28*
	(2.21)	(0.02)	(0.16)
N	3619	3619	1057
R-Squared	0.46	0.34	0.39
Control Group Mean	26.95	0.82	2.66
Topography	Y	Y	Y
Locality FE	Y	Y	Y
Boundary FE	Y	Y	Y

* 0.10 ** 0.05 *** 0.01

Notes: This table is similar to Table 2 but assigns observations to boundary segments using a 1 square-kilometer fishnet to chop Dutch polygons. The number of boundary fixed effects is 95 in columns 1 and 2 and 87 in column 3.

Table A4: Robustness to Spatial Correlation in Standard Errors

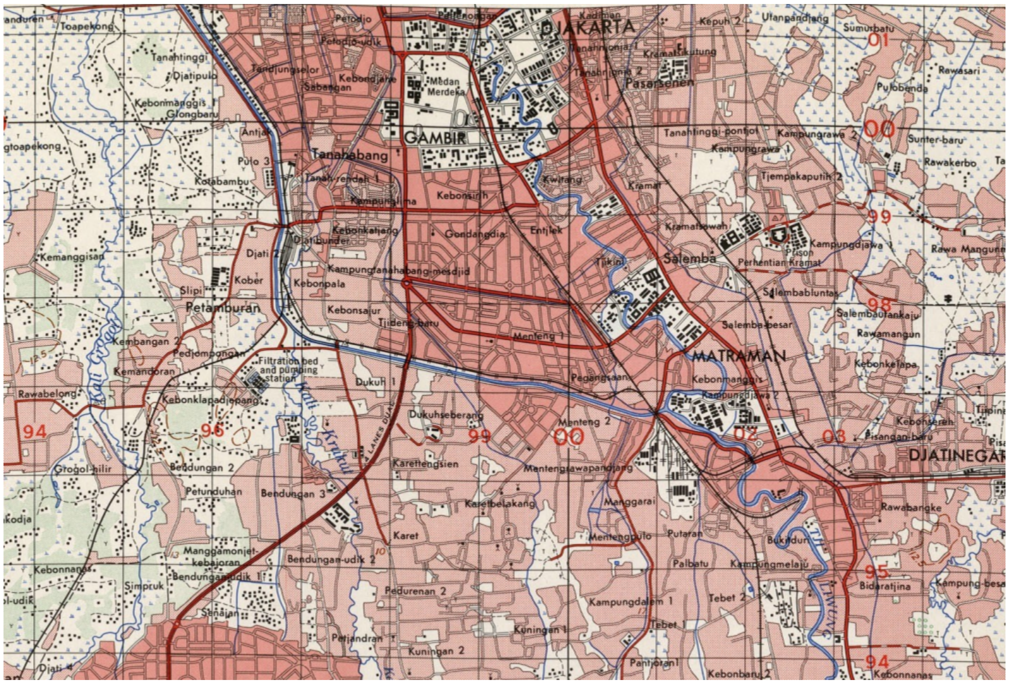
	P-values of ATE		
Dependent variable:	500m cutoff (1)	700m cutoff (2)	900m cutoff (3)
Share Kosong	0.02	0.02	0.01
Parcel Density	0.00	0.00	0.00
Slum Index	0.02	0.01	0.01

* 0.10 ** 0.05 *** 0.01

Notes: We repeat the analysis in Table 2 except we allow for spatial autocorrelation in standard errors (Conley, 1999) allowing for correlation over 500, 700, and 900 meters, respectively. 900 meters corresponds to the implied radius of a locality (the spatial unit for clustered standard errors).

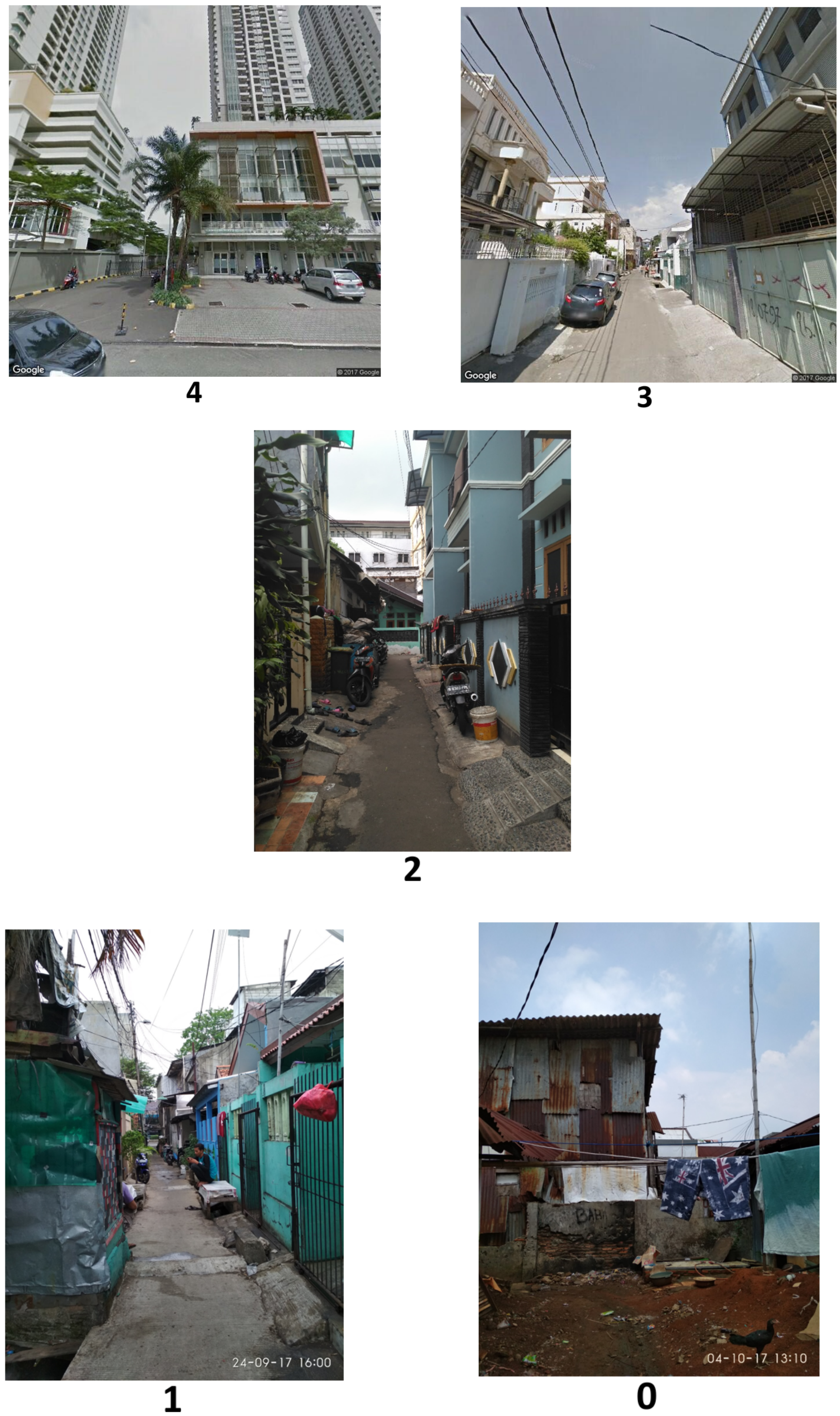
Appendix Figures

Figure A1: Example of One Historical Map of Jakarta



Notes: An example of a historical map. The darkest red areas are Dutch settlements, the lighter areas are traditional kampung settlements. Other areas that are coded include rice farms (blue symbol of padi) and orchards (light green circles).

Figure A2: Coding of the Photo Index



Notes: Examples of the ranking of formality. A value of 4 corresponds very formal and a value of 0 corresponds to very informal.